ENCLOSURE III

GENETIC MANAGEMENT STRATEGIES AND POPULATION VIABILITY OF THE

FLORIDA PANTHER

GENETIC MANAGEMENT STRATEGIES

AND POPULATION VIABILITY

OF THE

FLORIDA PANTHER
(*Felis concolor coryi*)

REPORT OF A WORKSHOP

White Oak Plantation Conservation Center

Yulee, Florida
21-22 October 1992

Supported in part by USFWS Contract # 14-16-0004-92-983,

White Oak Conservation Center,

and CBSG/SSC/IUCN

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Executive Summary

The Florida panther is one of the most critically endangered taxa in the United States. Population declines and associated inbreeding have resulted in significant losses in genetic variability and viability. Natural gene exchange existing historically between the Florida panther and other North American puma subspecies is no longer possible because of human induced isolation. Successful recovery of the Florida panther is doubtful without a reinstitution of lost gene flow.

The Florida Panther population was found to be at high risk of extinction over the next 25-40 years at the time of a population viability assessment in 1989 (Seal et al.). The analysis indicated that genetic heterozygosity would continue to be lost at the rate of about 6% per generation if the population was not increased in size. Substantial evidence for inbreeding depression was presented and led to the conclusion that the establishment and management of a captive population was the only way to preserve existing genetic viability. Delays, imposed by external events, prevented timely implementation of management actions to establish the captive population, rapidly expand the population, and secure full representation of the genetic diversity present in the population at that time.

Renewed concerns over reduced levels of genetic heterozygosity and the complete loss of historic gene flow patterns led to a workshop in 1991 to consider genetic augmentation as a tool in Florida panther recovery (Seal editor, 1991). General conditions and criteria for the use of genetic augmentation to ameliorate the adverse effects of inbreeding depression in a population were formulated in the workshop. These criteria were applied, at that workshop, to the Florida panther population with the determination that there was substantial evidence for inbreeding depression and that genetic augmentation should be undertaken.

The present Workshop was convened because of increasing evidence that the population displays multiple physiologic abnormalities that are likely a consequence of recent close inbreeding among the surviving individuals. Re-evaluation of the wild population viability indicates that it is continuing to decline genetically, remains at high risk of extinction, and that adverse effects of inbreeding are accumulating rapidly. It was the consensus of the Workshop participants that the reinstitution of historic gene flow between the Florida panther and adjoining Felis concolor subspecies, i.e., genetic augmentation, is needed to reverse these effects of inbreeding depression, that effective action needs to be taken quickly and that the amount of introgression required may reach 20%.

Eight alternative management scenarios for controlled introgression of genetic material from another population of Felis concolor were examined in terms of: accomplishing the biological objectives, evaluating population source of the individuals to be used for the intercrosses, accessibility of Florida panther and intercross animal, timing, availability of the requisite technology, and possible adverse effects on the individual animals. The scenarios given top priority were (1) direct introduction of animals into suitable unoccupied territories or potential territories, (2) AI of females brought into captivity for a brief period of time and then returned to the wild, and (3) breeding or AI of non-Florida animals in captivity with Florida panther males or their sperm. All 3 scenarios will need to be implemented in parallel given the time span required, the high incidence of abnormalities in the population, and the continued loss of animals from the wild population.

GENETIC MANAGEMENT STRATEGIES FOR THE FLORIDA PANTHER

Workshop Report

22 October 1992

Introduction

Historically, the Florida panther, *Felis concolor coryi*, ranged across much of the southeastern United States. Today, it is one of this nation's most critically endangered taxa. A single population in southern Florida, estimated to consist of 30 to 50 adults, is all that remains in the wild. Population declines and associated inbreeding have resulted in significant losses in genetic variability and viability. Natural gene exchange, existing historically with other populations of *F. c. coryi* and other *F. concolor* subspecies (Young and Goldman reported gene exchange between *F. c. coryi* and *F. c. cougar* to the north and to the west and northwest with *F. c. stanleyana* and *F. c. hippolestes*), is no longer possible because of isolation. Analysis of the present status of the endangered Florida panther (*Felis concolor coryi*) indicates that the population exhibits multiple physiologic abnormalities that are likely a consequence of recent close inbreeding among surviving individuals. To correct this serious and rapidly deteriorating situation, the consensus of the workshop was to immediately reinstate gene flow (or genetic augmentation) lost because of human caused isolation. The goal of the recommended genetic augmentation is to reverse the consequences of inbreeding as well as to reconstitute genetic variation that may have occurred naturally in Florida panthers when its former range and the ranges of adjacent subspecies were occupied.

The consequences of demographic contraction in the Florida panther are evident from a decade of field and biomedical monitoring. The Florida panther, reduced to less than 50 adult individuals in south Florida by human depredation and habitat depletion, display a remarkable array of genetic and physiologic impairments that pose a direct threat to survival. Relative to other puma subspecies the Florida panther has reduced genetic variation based upon mitochondrial DNA, allozyme and DNA fingerprint analyses, likely a result of genetic drift and close inbreeding caused by range and population contractions. Several cases of consanguineous matings have been documented directly in the surviving population.

Correlated with the genetic uniformity is the occurrence of several aberrant congenital defects including:

1) an average incidence of 95% morphologically-abnormal sperm per ejaculate (including a 41% incidence of malformed spermatozoal acrosomes), in contrast to

western or South American samples that have an incidence of 83% and 58% abnormal sperm respectively;

2) 71% cryptorchidism in living males (12 of 17) with 12% (2 of 17 living males) of these being bilateral and, thus, sterile;

3) emergence of fatal cardiac abnormalities.

Furthermore, the population has suffered from a score of pathological infectious agents that have been fatal in 8 panthers to date. These infections may be a consequence of a defective immune system compromised by inbreeding. Combined with the non-physiological perils that contribute to mortality (e.g. road kills, intra-specific aggression, mercury toxicity) and interacting stochastic effects that threaten the population (e.g. demographic fluctuations, genetic drift), the results indicate a precarious population at high risk for extinction. The cumulative results strongly indicate an imperative to manage more directly the residual genetic representation of the remaining population and support the reinstatement of gene flow with conspecific populations of puma.

In May 1991 a workshop was convened in Washington D. C. to consider "Genetic Management Considerations for Threatened Species with a Detailed Analysis of the Florida Panther". The report of that workshop (attached to this report) developed explicit criteria for considering genetic augmentation of an endangered population when inbreeding and associated consequences negatively affect population viability. These criteria were reexamined by the present group and applied to the available knowledge about the Florida panther. Our conclusion is that the Florida panther's status is sufficiently grave to recommend immediate implementation of a genetic augmentation program as outlined below.

A managed reinstitution of gene flow between *F. c. coryi* and a historic adjacent *F. concolor* subspecies would likely improve the genetic health and viability of the extant Florida panther gene pool. Although genetic augmentation is recommended and represents a management attempt to reconstitute the genetic variation that was once present in the ancestors of today's population, we emphasize that this measure does not address the need to identify and designate increased suitable panther habitat required to sustain a demographically viable population with a high confidence of persistence.

Sources and Levels of Genetic Augmentation

The primary goal of genetic augmentation for the Florida panther is the reduction in frequency of deleterious traits that can result from inbreeding by introducing genetic material from other *Felis concolor* populations. For such situations, the workshop on 'intercrossing' ("Genetic Management Considerations for Threatened Species with a

Detailed Consideration of the Florida Panther" 30-31 May 1991) recommended a small percentage of admixture of non-local genes in a single episode. The amount of genetic admixture should be sufficient for the target population to recover from the deleterious effects of inbreeding, but not so large as to swamp the local gene pool which may be adapted to local environmental conditions. A small admixture of non-local genetic material into a population suffering from inbreeding depression should permit natural selection to reduce the frequency of deleterious mutations over the course of several generations while maintaining local adaptations. The amount of admixture chosen for a given management program represents a tradeoff between rapid recovery from inbreeding effects and possible swamping of local adaptations. Because of the recent rapid increase in frequency of cryptorchidism and heart defects, and documented cases of close inbreeding in the wild Florida panther population, the panel members recommend immediate genetic augmentation of the population by introduction of 20% of the target population's genetic material from another puma population to rapidly reverse the deleterious effects of inbreeding within two or three generations.

A crucial part of the management strategy is that the initial genetic admixture should be monitored to track its spread through the Florida population to confirm recovery of intercrossed offspring from the proposed deleterious effects of past inbreeding, and to determine if and when further admixture is necessary.

A secondary, long-term goal of genetic augmentation is to maintain genetic variability in the Florida panther population at levels comparable to the historic panther population and to other *F. concolor* populations, to allow natural selection and adaption to environmental changes. After the initial augmentation, this can be accomplished by continued introduction from a non-Florida population of about one successful breeding individual every generation (generation time=6 yrs). Augmentation may also be considered or required for demographic purposes.

In a target population as small as the Florida panther, with 30 to 50 adult individuals, the primary goal can be met by introducing 6 to 10 unrelated, successful non-Florida individuals, or twice as many unrelated, successful F1 intercrosses between Florida stock and another population. One advantage of introducing a larger number of intercross individuals is that there is less risk that their genetic contribution will be completely lost from the population before integration by chance demographic events. Intercross individuals are also more likely to be adapted to local environmental conditions than non-Florida animals, if local adaptations exist.

To be genetically effective, individuals introduced into the target population must become part of the breeding pool. The behavior and social structure of panthers suggests that this may best be accomplished by introducing subadult intercross or non-Florida females (or as a second choice subadult males) into vacant territories. Another option is artificial insemination of wild females by non-Florida or intercross males, if existing techniques can be refined.

There are six possible source populations for genetic augmentation of the Florida panther population:

1. Captive generic *F. concolor's* of known ancestry.

2. Piper captive stock (intercrosses between Florida, South American and possibly other *F. concolor's*.

3. "Everglades" panthers (intercrosses between early Piper stock and Florida panthers).

4. Wild Texas *F. concolor's*.

5. Wild Western (non-Texas) *F. concolor's*.

6. Central American or South American wild *F. concolor's*.

Of these six possible source populations, captive stocks 1 and 2 have the disadvantage that they may be partially adapted (behaviorally and/or genetically) to captivity, and less adapted to the Florida habitat than any wild population. "Everglades" panthers are already part of the present wild panther population, but because of their intercross ancestry do not, at this time, experience the high frequency of cryptorchidism or heart defects characterizing the remaining Florida panthers. However, they do have a similarly high incidence of sperm abnormalities that may or may not improve upon intercrossing with other Florida panthers. If the overall Florida panther population were demographically stable, natural intercrossing with "Everglades" individuals might eventually reverse most or all of the deleterious characters in the Florida panther. But the small numbers of "Everglades" panthers, the fact that they have a high proportion of Florida panther genes, and their peripheral location in relation to the main Florida population suggest that it would take several generations for their genetic contribution to naturally spread through the Florida population and perhaps still achieve slight improvement at best. All of these considerations dictate that genetic augmentation of the Florida panther population should be conducted with genetic material from a separate wild population.

Because of the small amount of genetic differentiation among puma populations throughout their range, and the absence of barriers to intercrossing between puma populations, it probably does not make much difference which wild population is used for genetic augmentation. However, a single wild puma population should be chosen for genetic augmentation of the Florida panther, and when the source population is determined, genetic studies on it should be conducted in conjunction with introduction and intercross efforts to characterize the introduced gene pool for monitoring and follow up studies.

Of the existing sources, wild Texas pumas formerly constituted part of a continuous range across which genetic material was likely exchanged with the Florida subspecies. For restoring the genetic fitness and natural pattern of genetic variation in the Florida panther, wild Texas pumas therefore appear to be the best source for genetic admixture. However, Texas puma populations sampled have also exhibited low genetic variation.

Possible Scenarios for Florida Panther Management With and Without Introgression.

The following is a list of management options that involve varying degrees of introgression. The list is ordered from the most drastic introgression (elimination and replacement of native stock) to the least drastic intervention (no action). The options are not mutually exclusive and some can be used in combination. For each option we have described some of the conspicuous advantages and disadvantages. All of the options that involve introgression (1-5) have the advantage that they would help the wild Florida population recover from inbreeding depression (i.e., lower the incidence of undescended testes, incompetent sperm, etc.). Such recovery would be immediate in the sense that intercrossed animals will not express its recessive genetic defects. The options that do not involve introgression (6-9) will not correct the genetic problems of the south Florida panther population but could have beneficial demographic effects.

<u>1. Eliminate native stock and replace with non-Florida stock.</u>

The present Florida panther population is genetically unique. This population is currently surviving and reproducing with apparent natural mortality and natality rates but showing signs of inbreeding depression. Elimination of this population would mean the extinction of a subspecies. Introduction of non-Florida individual may be met with high mortality due to dispersal and environmental factors. Finally, it is not necessary to institute a drastic plan of replacement when the current problems with genetic vitality can be more simply addressed through genetic augmentation.

2. Artificial insemination of south Florida females with sperm from non-Florida males.

This scenario includes the use of artificial insemination (AI) of free-living females to produce genetically-enhanced offspring in situ. Using frozen sperm from non-Florida males, this approach would rapidly place new genetic material into the wild population without disturbing the social structure of the free-living animals.

The greatest challenge associated with this scenario is the difficulty of manipulating females under field (uncontrolled) conditions. Timing of hormonal stimulation for the induction of estrus is critical to AI success. For this reason, the technique may require that females be removed from the wild for 30 days for the administration of hormones and AI, and released back into the wild immediately following inseminating. The disadvantage of this approach would be the unknowns associated with potential behavioral and physiological stress related to short-term captivity.

The reproductive biology techniques can be developed in conjunction with the captive breeding program. If field related problems preclude AI being used in the field, the technology could be useful in the captive breeding program and for the release or reintroduction of inseminated wild-caught or intercross females.

3. Translocation of wild non-Florida subspecies into south Florida.

The most expedient route for introducing genetic material into the south Florida panther population is to relocate individuals from another appropriate wild *F. concolor* population. The recommended action would involve capture of young (12-18 month old) non-Florida females and release (following only quarantine as necessary to assure that no diseases are carried) into vacant female Florida panther home ranges. Because female panthers are generally philopatric (do not disperse) and subadults are unattached to a home range, this sex and age class would be most likely to stay where released. In addition, introduced subadult females would be unlikely to interact aggressively with local residents. While subadult non-Florida males could also be used, the low frequency of male recruitment would probably delay the genetic contribution of these individuals for several years. Furthermore, the propensity for long distance dispersal by males increases the chances for mortality or travel to less desirable areas of panther range.

Advantages of this approach include very low cost (individual could be kept in captivity for a minimal, mandatory quarantine period) and very low probability of disrupting the existing social organization of south Florida panthers.

Disadvantages include less knowledge of medical history (compared with captive reared individuals) and a relatively slow incorporation of genetic benefits (compared with AI).

Offspring produced from non-Florida x Florida panther matings should be evaluated and radio-instrumented before they disperse in order to score key traits (e.g., incidence of cryptorchidism, heart murmurs, etc.) and to monitor survival and recruitment. Tissue samples should be collected at the first opportunity so that the progeny of these animals can be recognized by DNA fingerprints.

4. Release of captive-raised non-Florida *F.concolor's* into south Florida.

This option differs from direct translocation of wild non-Florida subspecies (option 3) in that the source of animals will be captive-raised and conditioned non-Florida individuals. Variations using males versus females follow the same rationale suggested for Option 3.

An advantage of this approach is that the medical condition and history of released animals is better controlled and understood with little chance of introducing an unwanted pathogen into south Florida.

A possible disadvantage of this approach is that the adaptability of captive raised individuals to the wild is unknown and could influence success. The cost of raising (housing, feeding, etc.) individuals would be high.

5. Captive production and reintroduction of intercrossed panthers.

Florida panthers could be intercrossed with non-Florida individuals with the aim of reintroducing first-, second- or later- generation crosses to south Florida. Intercrosses may have a better chance of surviving and reproducing than non-Florida individuals. Furthermore, planned captive introgression may be more successful than simple propagation (option 6) in perpetuating south Florida panther genotypes. In particular, using non-Florida animals greatly expands the number of breeding options. For example, using non-Florida males as mates for Florida females circumvents the testicular and sperm problems that plague Florida males. Putting problems of breeding space and facilities aside, intercross production could also be used as an adjunct to captive propagation of Florida panthers. Reproductively competent male Florida panthers could be used to sire the litters of both Florida and non-Florida females. Under these or other scenarios involving intercrosses, a set of guidelines should be produced to steer the breeding program. Without guidelines and monitoring (e.g., with DNA fingerprints) a breeding program could produce animals of uncertain parentage.

6. Captive propagation of south Florida panthers without introgression.

The advantage of this option is that native genetic stock could be perpetuated for later reintroduction. Furthermore, the captive population could act as insurance against natural catastrophes or more gradual extinction of the wild population. Captive propagation does face problems. The overall health and vigor of Florida panthers has been compromised by genetic defects and pathogens. Compared with individuals from outbred populations, Florida panthers may prove to be difficult to breed in captivity. Secondly, the available stock in nature is currently limited to at most **two or three dozen** animals. Third, the panther that currently exists only partially resembles the historic population genetically and physiologically. Fourth, this option perpetuates the problem we have as a result of inbreeding depression. Finally, breeding facilities and space are currently limited and would have to be expanded. Optimistically, captivity may offer an opportunity to ameliorate the health problems of wild animals and to improve their breeding.

7. Shuffle animals between locations in south Florida.

Such a program could help equalize the reproductive success of individuals (particularly males) and so increase the effective population size and delay loss of genetic variation. For example, dominant male #12 is probably over-represented genetically in the Florida panther population and due to his relatedness with most of the females (daughters, grand-daughters, etc.) may be exacerbating the rate of inbreeding. Replacing this dominant male with a non-related peripheral male would provide an opportunity to introduce new genetic material and for a short time, decrease the rate of inbreeding. This dominant male and any other surplus males could be removed and used with non-Florida females to establish a new population in a reintroduction site. If the removed dominant male's home range is allowed to fill naturally, there is a high probability that he will be successfully replaced by a local, peripheral male. On the other hand, if a peripheral male is moved from Big Cypress National Preserve (e.g., #42) or Everglades National Park (e.g., #16) into the vacant range, there is a chance that the introduced male will home and not establish himself where he is needed. Also, the new male may be killed by intra-specific fighting, or he may kill other males or females. This option does less to correct genetic defects than introduced non-Florida genes. This option would allow demographic management but may not solve genetic problems.

8. Use surplus south Florida males and non-Florida females to found new populations in Reintroduction sites.

Under this option at least some Florida genotypes are perpetuated but in an intercrossed background. Young male panthers have limited options for dispersal and establishment in south Florida and several have been killed in intra-specific fighting. This option involves the removal of surplus male panthers in the south Florida population for translocation and reintroduction. This options assumes that males can be identified for translocation to sites that are unoccupied by panthers. Female non-Florida individuals would be placed into the reintroduction area with the males. This option would allow the opportunity for young male panthers to establish territories, breed with non-Florida individuals and produce intercross offspring.

9. Leave the Florida panthers where they are, without introgression.

Inaction does not appear to be a viable option. Without some sort of intervention the current wild population of Florida panthers is expected to become extinct within 25-50 years (see updated Population Viability Analysis below).

Reassessment of the Viability of the Florida Panther Population in the Absence of Further Intervention.

A. Data for Parameters of Population Viability Analysis

The 1989 Population Viability Analysis workshop concluded that the present population of Florida panthers was vulnerable to extinction within the next few decades, due to the combined effects of multiple sources of mortality and stochastic demographic and genetic instability. Since the 1989 workshop, additional data on mortality and reproduction have become available from the radio-collaring studies. These newer data have been incorporated into revised viability analyses, as described below. A more complete description of the bases of the estimates of population parameters and description of the simulation model are presented in the original PVA report (Seal et al. 1989).

1. Mortality

Mortality of radio-collared panthers has been somewhat lower than reported during the 1989 PVA workshop. Over the entire course of the radio-collaring studies (since 1981), 28 collared animals died during 1,444 animal-months of observation. This yields an annual mortality estimate of 21% (monthly mortality = 28/1444 = .0194; monthly survival = .9806; annual survival = $(.9806)^{12}$ = .7906; annual mortality = .2094). Because mortality was higher and samples sizes smaller during the early years of collaring, mortality was also estimated from data collected since 1/1/85. Between 1/1/85 and 6/30/92, 23 deaths occurred during 1,257 animal-months of observation, yielding an annual mortality of 20%. This estimate was used in the revised analyses. Animals were assumed to become post-reproductive and, hence, no longer capable of contributing to the population at age 12.

2. Reproduction and juvenile mortality

Data presented in the Florida Game Fresh Water Fish Commission annual medical reports indicate that approximately half of the litters observed or inferred to have been produced died at early ages. Among surviving litters, the mean litter size observed has been 1.9. However, data from known litters within the core study area indicate that, except for litters rapidly replaced, perhaps as few as 20% of litters die. In the Everglades National Park, three of six known litters were lost.

For the modelling analysis, we assumed a mean litter size of 2, distributed as 25% litters of one, 50% litters of two, and 25% litters of three. First year mortality was initially assumed to be 50%. To test the sensitivity of results to this uncertain parameter, scenarios were also examined with an assumption of 20% mortality of juveniles, as would occur if litters died when and only when the dam died (as adult mortality is 20%).

3. Age and frequency of breeding

Although some panthers have been observed to produce offspring by 2 years of age, it is not known whether this early age of breeding is typical or unusual. Analyses were conducted with breeding commencing either at 2 or at 3 years of age. Females were assumed to produce, on average, a litter every 24 months.

4. Breeding system

The population was assumed to be polygamous, with all adult females and half of the adult males in the breeding pool. The computer model assumes that the males within the breeding pool are reselected randomly each year.

5. Population size and carrying capacity

It is estimated that there is presently habitat in south Florida for about 50 adult panthers. If this habitat is saturated, then about 50 adults and about 25 young may exist in the population (Maehr et al. 1991). Some panther biologists have expressed concern that numbers might be lower. Analyses were conducted with either 30 or 50 initial animals (censuses prior to the breeding season) and with a habitat carrying capacity of 50.

6. Habitat loss

About 50% of the present panther habitat is on privately-owned lands, and an unknown fraction of that land is likely to be converted to uses that make it unsuitable for panthers in the coming few decades. Scenarios were assessed with no change in habitat, a 1% annual loss over 25 years (approximately 25% total loss), and a 2% annual loss over 25 years (approximately 50% total reduction in habitat).

7. Environmental variation

At this time, as in 1989, there are insufficient long-term data to allow estimating the annual fluctuations in birth and death rates that might be caused by variation in the environment. All modelling was conducted under the assumption that birth and death rates are subjected to no environmental variation. If environmental variation was substantial, it would further destabilize the population relative to the results presented here.

8. Effects of inbreeding

Although the deleterious effects of inbreeding appear to be impacting the panther population, it is not known, quantitatively, how severely inbreeding has reduced fitness, nor how it will further impact fitness if the panthers become even more inbred. Models were assessed under an assumption of no effect of further inbreeding, an assumption of 1 recessive lethal per present animal (a moderately low impact), or an assumption of 3 lethal equivalents (modelled as heterotic, rather than recessive, effects) per animal, as is typical of many other species of mammals.

B. Population Viability Analysis Results

Each scenario described above was examined by simulating 250 populations with the population viability analysis program VORTEX (Lacy, in press). The following tables present the population fates projected 25 years, 50 years, 100 years, and 200 years into the future. The input parameters that varied among scenarios are described at the top of the tables and in the first four columns. The six tables show the results for three levels of inbreeding depression with either 50% or 20% juvenile mortality. Inbreeding depression (Inbreeding depression) was set at 0, at 1 recessive lethal per individual, or at 3 lethal equivalents. Initial population size (N_0) was set at 30 or 50 (just prior to the breeding season). Carrying capacity (K) was assumed to remain stable, decrease at 1% annually, or decrease at 2% annually for 25 years. First breeding by both sexes was assumed to occur at 2 years or at 3 years of age.

The mean and standard deviation of the exponential growth rate (r) observed in the simulated populations, prior to any carrying capacity truncation each year are given in the next two columns of each table. The probability of extinction (PE), mean size (N_t) and standard deviation in size of those simulated populations not yet extinct, and the mean proportion still remaining of the initial expected heterozygosity (H) or gene diversity are presented at 25 year, 50 year, 100 year, and 200 year intervals. The median time to extinction (TE) for those scenarios in which at least 50% of the simulated population went extinct is given in the last column of each table. Because of rounding, scenario results occasionally show a mean size and heterozygosity of remaining populations when the (rounded off) probability of extinction is displayed as 100%. These are cases in which the probability of extinction was 99.6% (249 out of 250 simulations).

The expected deterministic population growth rate (r) for the scenarios, calculated from standard life table analysis of birth and death rates, assuming no fluctuations in annual rates, is given at the bottom of each table.

C. Discussion

The revised population viability analyses project that the population is both demographically and genetically unstable, and is likely to become extinct within about 24 to 63 years if juvenile mortality is 50%. The effects of higher survival, but lower litter size, estimated from current data relative to the earlier analyses, are approximately offsetting, and the results presented here do not lead to substantially different conclusions than those that arose from the 1989 population viability analysis. Population biology parameters estimated from field research do not ensure a self-sustaining population. The time and certainty of extinction varies under the various scenarios analyzed, but all suggest that the population will be highly vulnerable to extinction if genetic, habitat, and demographic conditions cannot be improved.

If juvenile mortality is as low as is adult mortality (20%), the population would show, on average, positive population growth, but it is still subjected to inbreeding depression and random demographic effects that can cause extinctions. In particular, if the effects of inbreeding on juvenile mortality are similar to the median effects seen in other mammalian species (Ralls et al., 1988), the joint and synergistic effects of demographic fluctuations and inbreeding virtually always drive the simulated populations to extinction.

Although there is a possibility of population survival under the scenarios that assume weak or no impact of inbreeding and 20% juvenile mortality, the population was projected to become highly inbred (beyond the inbreeding that has already occurred) within a few generations. Those simulated populations which did survive contained little genetic variation, generally at levels expected after about four to nine generations of brother-sister or parent-offspring matings (about 32% and 8% of present genetic variation, respectively). However, the much greater and longer stability of the simulated populations when there is low juvenile mortality and no effects of inbreeding indicates that if genetic problems can be avoided through managed introduction of genetically divergent stock and continued movement of genetic material, and if juvenile mortality can be kept low, the south Florida population of panthers can be a demographic "source" population as a component of a metapopulation of panthers, rather than the "sink" that is projected if inbreeding effects accumulate or if juvenile mortality is about 50%.

D. Literature cited

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Florida panther population viability without further intervention: No inbreeding effects, 50% juvenile mortality																							
Inbr. depr.	N_0	Change in K: 25 yrs	1st breed	Growth: r		25 yr results				50 yr results				100 yr results				200 yr results				TH E
				mean	SD	PE	N_t	SD	H	PE	N_t	SD	H	PE	N_t	SD	H	PE	N_t	SD	H	
None	30	-2%/yr	2	-.042	.204	14	17	7	76	55	12	7	51	92	12	7	22	100	4	0	0	47
			3	-.082	.223	34	10	6	72	92	9	6	53	100	--	--	--	100	--	--	--	30
		-1%/yr	2	-.039	.199	11	19	10	76	48	18	10	58	85	16	11	37	98	22	5	30	53
			3	-.081	.226	34	11	7	70	87	9	7	50	100	5	0	18	100	--	--	--	31
		None	2	-.040	.193	16	22	12	78	46	18	12	60	85	20	13	35	99	15	3	4	53
			3	-.083	.225	38	11	6	72	87	9	6	55	100	--	--	--	100	--	--	--	29
	50	-2%/yr	2	-.040	.200	5	18	7	81	46	13	7	56	86	13	7	25	100	--	--	--	53
			3	-.083	.201	22	12	7	79	84	9	6	53	100	--	--	--	100	--	--	--	35
		-1%/yr	2	-.039	.186	6	22	10	82	44	17	10	59	82	19	10	31	97	17	9	17	56
			3	-.080	.210	18	13	8	78	81	10	7	57	99	6	1	22	100	--	--	--	35
		None	2	-.035	.178	3	26	13	83	31	21	13	67	76	21	12	41	95	23	18	21	63
			3	-.079	.208	18	14	8	79	80	9	6	58	100	--	--	--	100	--	--	--	38

Note: deterministic r (from life table) = -.018 with breeding at 2, r = -.056 with breeding at 3.

Florida panther population viability without further intervention: 3 lethal equivalents, 50% juvenile mortality

Inbr. depr.	N_0	Change in K: 25 yrs	1st breed	Growth: r		25 yr results				50 yr results				100 yr results				200 yr results				TE
				mean	SD	PE	N_t	SD	H	PE	N_t	SD	H	PE	N_t	SD	H	PE	N_t	SD	H	
3 H	30	-2%/yr	2	-.077	.207	25	13	7	76	92	5	3	54	100	--	--	--	100	--	--	--	33
			3	-.108	.227	53	8	5	72	99	5	2	35	100	--	--	--	100	--	--	--	24
		-1%/yr	2	-.080	.213	26	13	8	76	91	7	4	56	100	--	--	--	100	--	--	--	32
			3	-.104	.225	53	8	5	72	98	3	1	33	100	--	--	--	100	--	--	--	25
		None	2	-.079	.215	19	15	11	75	86	8	6	54	100	--	--	--	100	--	--	--	35
			3	-.102	.227	51	8	5	73	100	2	0.	38	100	--	--	--	100	--	--	--	25
	50	-2%/yr	2	-.073	.199	8	15	7	80	82	7	4	59	100	--	--	--	100	--	--	--	39
			3	-.102	.213	28	10	6	77	98	4	3	51	100	--	--	--	100	--	--	--	31
		-1%/yr	2	-.069	.194	3	19	9	82	71	9	6	58	100	--	--	--	100	--	--	--	44
			3	-.100	.209	27	11	6	78	98	5	6	56	100	--	--	--	100	--	--	--	31
		None	2	-.073	.194	7	20	12	82	75	10	7	62	100	--	--	--	100	--	--	--	40
			3	-.100	.216	26	11	6	77	95	5	2	46	100	--	--	--	100	--	--	--	31

Note: deterministic r (from life table) = -.018 with breeding at 2, r = -.056 with breeding at 3.

Florida panther population viability without further intervention: 1 recessive lethal, 50% juvenile mortality																							
Inbr. depr.	N_0	Change in K: 25 yrs	1st breed	Growth: r		25 yr results				50 yr results				100 yr results				200 yr results				TE
				mean	SD	PE	N_t	SD	H	PE	N_t	SD	H	PE	N_t	SD	H	PE	N_t	SD	H	
1 L	30	-2%/yr	2	-.050	.204	14	15	7	77	61	12	6	54	96	12	7	7	100	--	--	--	42
			3	-.085	.223	38	9	6	73	93	8	7	55	100	--	--	--	100	--	--	--	28
		-1%/yr	2	-.049	.201	20	18	10	78	62	15	9	56	92	16	10	32	100	5	0	0	42
			3	-.091	.226	44	9	6	70	93	8	5	52	100	4	0	22	100	--	--	--	27
		None	2	-.047	.198	18	19	11	78	56	16	12	56	89	17	11	36	99	18	14	22	46
			3	-.091	.226	42	10	6	73	93	11	8	47	100	--	--	--	100	--	--	--	28
	50	-2%/yr	2	-.046	.196	7	17	7	82	55	13	7	61	94	13	7	29	100	25	0	0	47
			3	-.087	.207	22	12	6	79	88	7	4	51	100	--	--	--	100	--	--	--	34
		-1%/yr	2	-.049	.194	5	21	10	83	50	15	9	62	93	15	9	31	100	--	--	--	50
			3	-.085	.208	17	13	8	80	85	9	7	60	100	3	0	44	100	--	--	--	35
		None	2	-.044	.185	5	24	13	84	43	20	13	68	87	20	14	42	99	13	6	0	58
			3	-.088	.213	20	12	8	79	82	8	5	55	100	--	--	--	100	--	--	--	34

Note: deterministic r (from life table) = -.018 with breeding at 2, r = -.056 with breeding at 3.

Florida panther population viability without further intervention: No inbreeding effects, 20% juvenile mortality																							
Inbr. depr.	N_e	Change in K: 25 yrs	1st breed	Growth: r		25 yr results				50 yr results				100 yr results				200 yr results				TE
				mean	SD	PE	N_t	SD	H	PE	N_t	SD	H	PE	N_t	SD	H	PE	N_t	SD	H	
None	30	-2%/yr	2	.063	.163	0	25	3	82	3	22	5	61	14	21	5	35	32	22	5	9	--
			3	.001	.109	4	23	5	81	18	17	7	62	58	18	7	34	87	17	7	14	85
		-1%/yr	2	.069	.128	0	36	4	84	1	34	5	70	2	34	5	48	5	34	5	21	--
			3	.006	.160	2	31	8	84	12	28	9	69	31	26	10	49	63	26	10	24	149
		None	2	.072	.109	0	48	5	85	0	47	5	75	0	48	4	57	1	48	5	34	--
			3	.011	.136	2	38	12	84	8	39	12	74	20	38	12	55	41	39	11	35	--
	50	-2%/yr	2	.062	.161	0	25	3	82	1	22	5	63	12	23	5	36	28	22	5	13	--
			3	.005	.185	1	23	4	84	19	18	7	65	52	17	7	39	84	17	7	14	98
		-1%/yr	2	.068	.129	0	36	4	85	1	35	5	71	4	34	5	51	8	34	5	25	--
			3	.008	.155	1	31	8	86	9	28	9	72	30	27	9	47	58	27	10	21	173
		None	2	.072	.108	0	48	4	87	0	48	5	77	0	48	5	59	1	47	6	38	--
			3	.014	.131	0	40	10	88	3	37	13	76	15	39	12	58	29	39	12	32	--

Note: deterministic r (from life table) = .081 with breeding at 2, r = .023 with breeding at 3.

Florida panther population viability without further intervention: 3 lethal equivalents, 20% juvenile mortality																						
Inbr. depr.	N_e	Change in K: 25 yrs	1st breed	Growth: r		25 yr results				50 yr results				100 yr results				200 yr results				TE
				mean	SD	PE	N_t	SD	H	PE	N_t	SD	H	PE	N_t	SD	H	PE	N_t	SD	H	
3 H	30	-2%/yr	2	-.010	.191	0	24	4	83	18	14	7	59	98	7	5	38	100	--	--	--	65
			3	-.037	.199	4	20	6	82	48	11	6	60	99	3	0	47	100	--	--	--	51
		-1%/yr	2	-.009	.177	0	34	6	85	6	26	9	70	79	10	8	39	100	--	--	--	85
			3	-.040	.192	6	26	10	83	37	15	9	66	98	5	1	14	100	--	--	--	56
		None	2	-.008	.166	1	45	8	86	4	37	12	75	54	18	12	53	100	--	--	--	98
			3	-.039	.189	2	30	14	83	32	22	13	71	94	8	3	52	100	--	--	--	64
	50	-2%/yr	2	-.005	.192	0	24	4	83	18	15	7	64	98	6	5	30	100	--	--	--	66
			3	-.036	.196	0	21	5	85	41	11	6	61	100	2	0	38	100	--	--	--	53
		-1%/yr	2	-.008	.175	0	34	6	86	4	24	10	72	80	10	8	45	100	--	--	--	83
			3	-.037	.186	0	28	9	86	22	17	10	70	98	5	3	46	100	--	--	--	63
		None	2	-.006	.162	0	46	6	88	1	41	10	77	42	21	13	53	100	12	0	22	108
			3	-.035	.175	1	36	12	88	14	23	13	74	91	8	5	48	100	--	--	--	71

Note: deterministic r (from life table) = .081 with breeding at 2, r = .023 with breeding at 3.

Florida panther population viability without further intervention: 1 Lethal recessive, 20% juvenile mortality

Inbr. depr.	N_0	Change in K: 25 yrs	1st breed	Growth: r		25 yr results				50 yr results				100 yr results				200 yr results				TE
				mean	SD	PE	N_t	SD	H	PE	N_t	SD	H	PE	N_t	SD	H	PE	N_t	SD	H	
1 L	30	-2%/yr	2	.054	.166	0	24	4	83	5	22	5	63	20	21	6	28	40	22	5	8	--
			3	-.003	.192	2	21	6	83	22	17	7	63	58	16	7	28	89	18	6	9	87
		-1%/yr	2	.065	.130	0	36	5	85	1	34	6	71	3	34	5	41	8	35	5	16	--
			3	-.001	.170	2	29	10	84	17	25	10	71	46	24	11	42	75	24	11	11	105
		None	2	.068	.110	0	47	7	87	0	47	5	76	0	47	7	55	1	48	5	25	--
			3	.006	.145	4	36	13	85	14	35	13	74	34	35	13	52	52	42	10	23	190
	50	-2%/yr	2	.056	.167	0	25	3	84	9	21	5	63	24	21	5	33	44	21	5	9	--
			3	-.006	.190	0	22	5	85	19	15	7	62	69	17	7	36	91	20	6	13	71
		-1%/yr	2	.066	.128	0	36	4	86	0	33	6	72	3	34	6	46	7	34	5	18	--
			3	.003	.161	0	31	8	87	10	25	9	73	35	25	10	42	65	27	9	15	141
		None	2	.068	.108	0	48	5	88	0	47	5	78	1	47	5	55	2	48	5	29	--
			3	.006	.139	0	38	12	88	8	36	13	77	27	36	13	55	46	36	14	25	--

Note: deterministic r (from life table) = .081 with breeding at 2, r = .023 with breeding at 3.

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